Investigating the Temperature-Dependent Performance of Plastic Scintillators

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Scintillating Plastics inside CMS

Within the Compact Muon Solenoid (CMS) detector at CERN, in Geneva, Switzerland, beams of protons are collided. In order to record these interactions, various particle detector technologies are used. One technology used is called scintillator, consisting of plastic and a primary and secondary dopant. As seen in Figure 1, when a particle passes through a scintillating sample, the particle deposits ionization energy in the sample and that energy is transferred to light-emitting dopants in the scintillator. The observed light output is proportional to the amount of energy the particle deposited when passing through the scintillating detector.

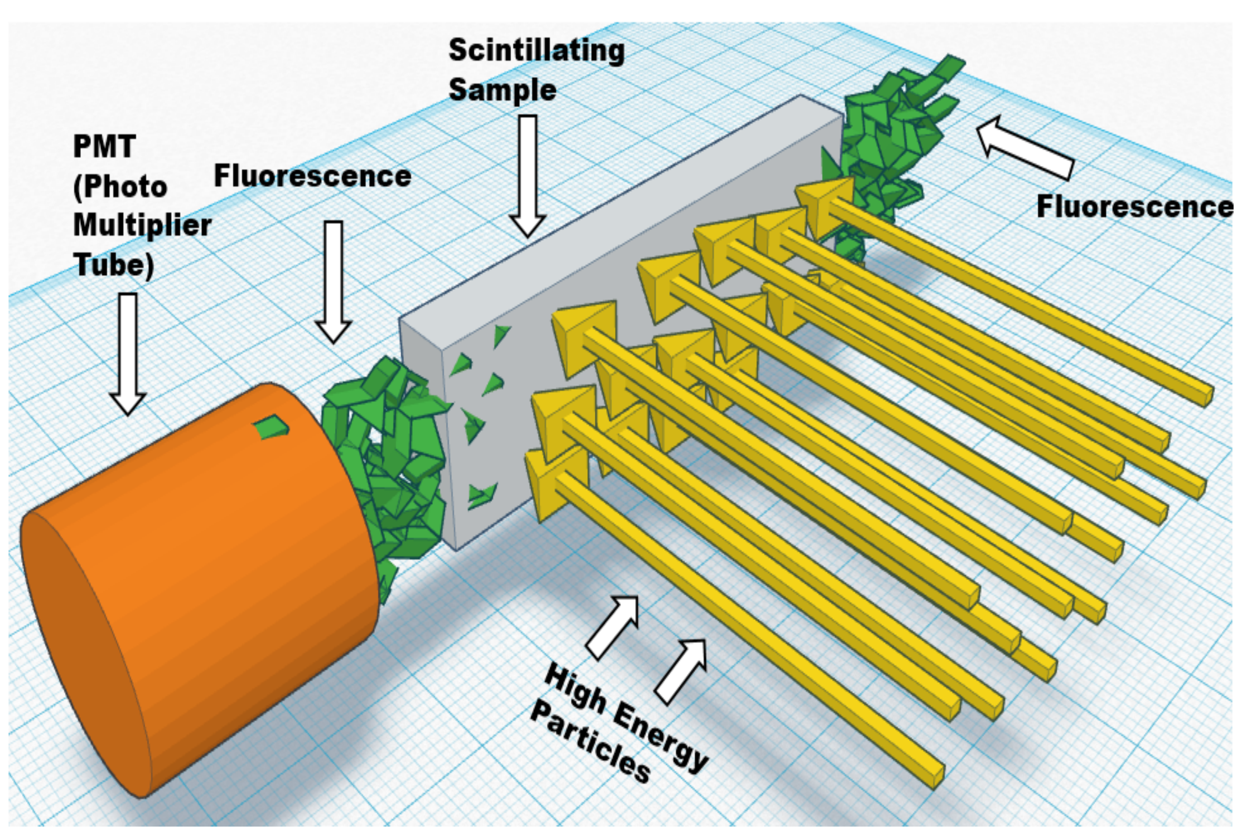


Figure 1: High-energy particles interact with a scintillating detector and cause the board to fluoresce. That fluorescence light is then transmitted to photodetectors that convert the light into an electrical signal.

The CMS experiment is undergoing constant changes and upgrades. A future upgrade will use silicon technology in the hadron calorimeter. Radiation damage in silicon is much reduced if it is operated at lower temperatures. The hadron calorimeter will also include scintillator, and it will be easier to engineer if the two technologies coexist in a similar temperature environment. My research project investigated the temperature-dependent performance of various commercially available plastic scintillators.

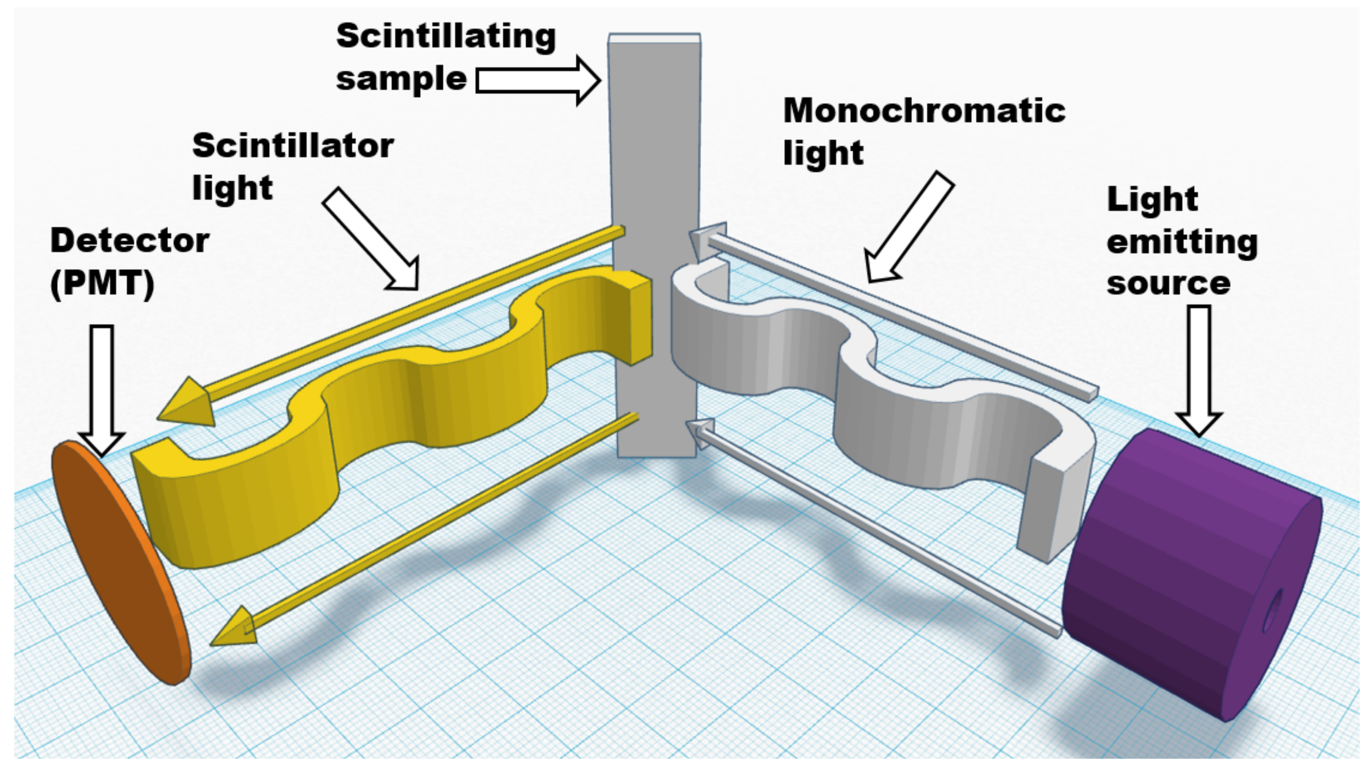


Figure 2: Setup of fluorescence spectrophotometer

Methodology

The fluorescence spectrophotometer was used to measure the emission spectrum of the scintillator. As seen in Figure 2, light emitted by a xenon lamp is passed through a monochrometer and illuminates a scintillator inside a glass tube (a thermal dewar). The light hits the plastic, fluorescing the primary dopant. The secondary dopant absorbs this primary light and then reemits it at a longer wavelength. A photomultiplier then converts the light into an electrical signal, which is then digitized and read out by a computer. In order to determine the temperature dependency, liquid nitrogen was used to cool the scintillator. We then observe the scintillator as the temperature rises to room temperature, 20°C, and analyze the data in order to determine the relative light output as a function of temperature.

Figure 3 shows the integration windows of a typical wavelength spectrum produced from the instrument.

PINK: emission from primary dopant

RED: emission from secondary dopant

GREEN: proportional to incident UV (250 nm). The wavelength is observed at 500 nm because it is the second diffraction peak in the spectrometer.

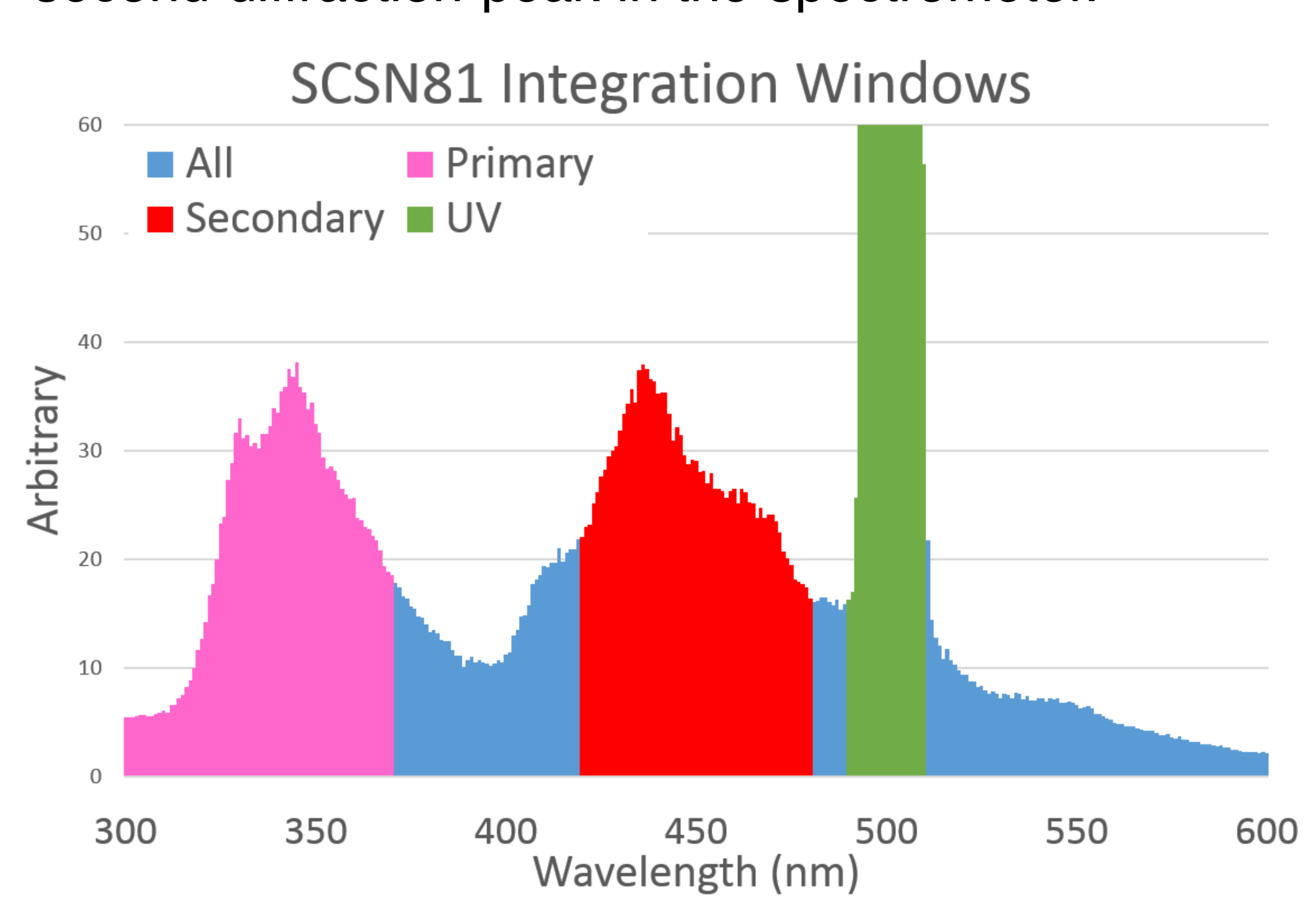
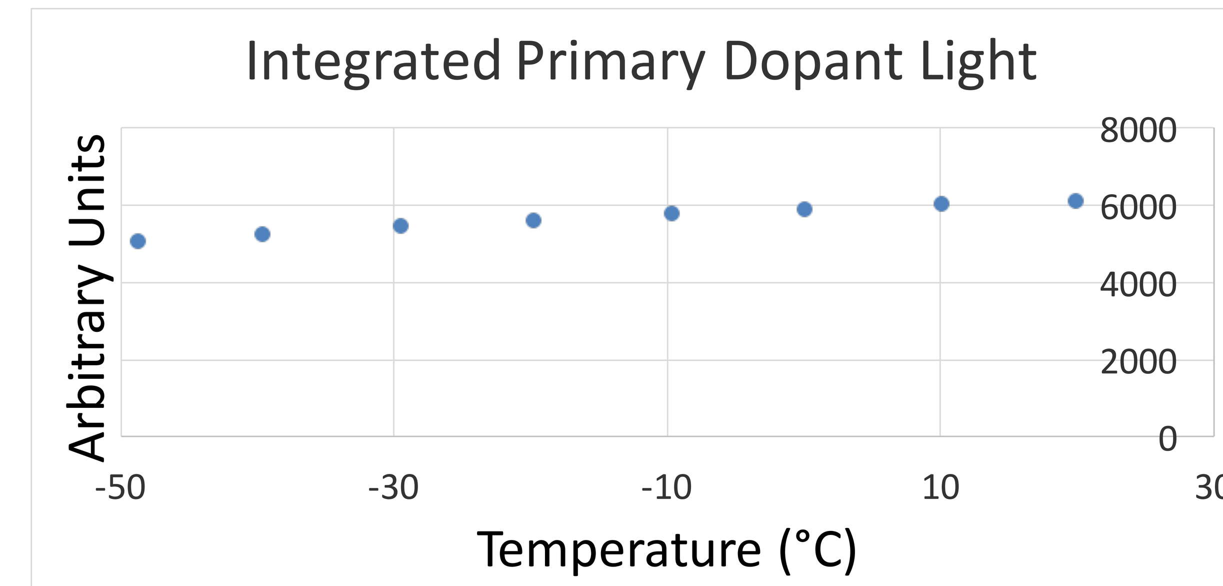
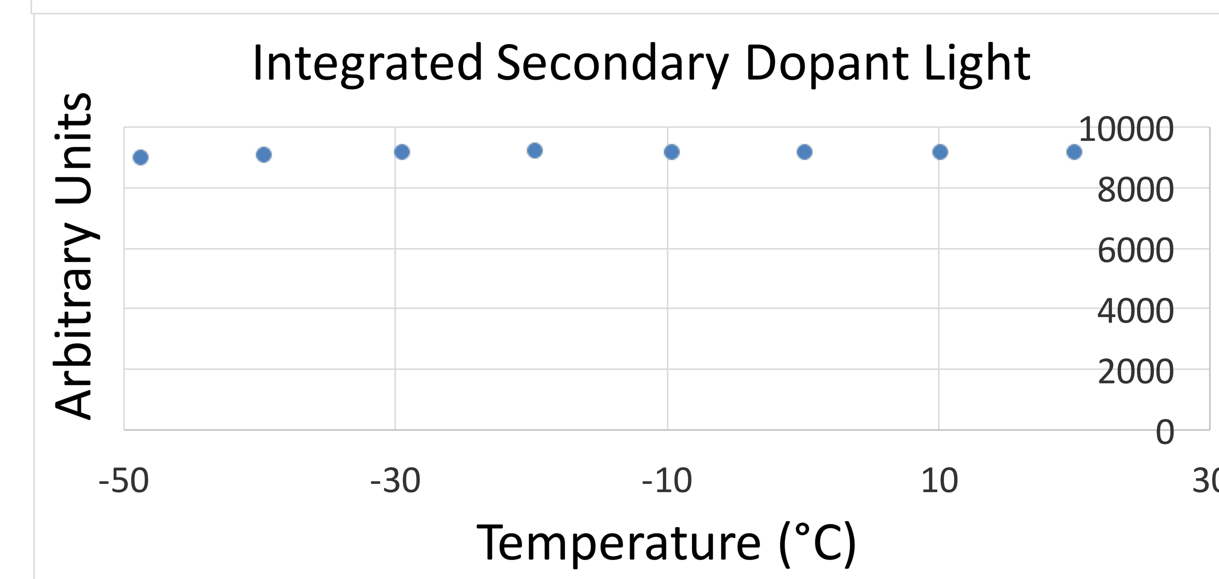


Figure 3: The spectrum represents the observed fluorescence spectrum of a scintillator sample (SCSN-81).

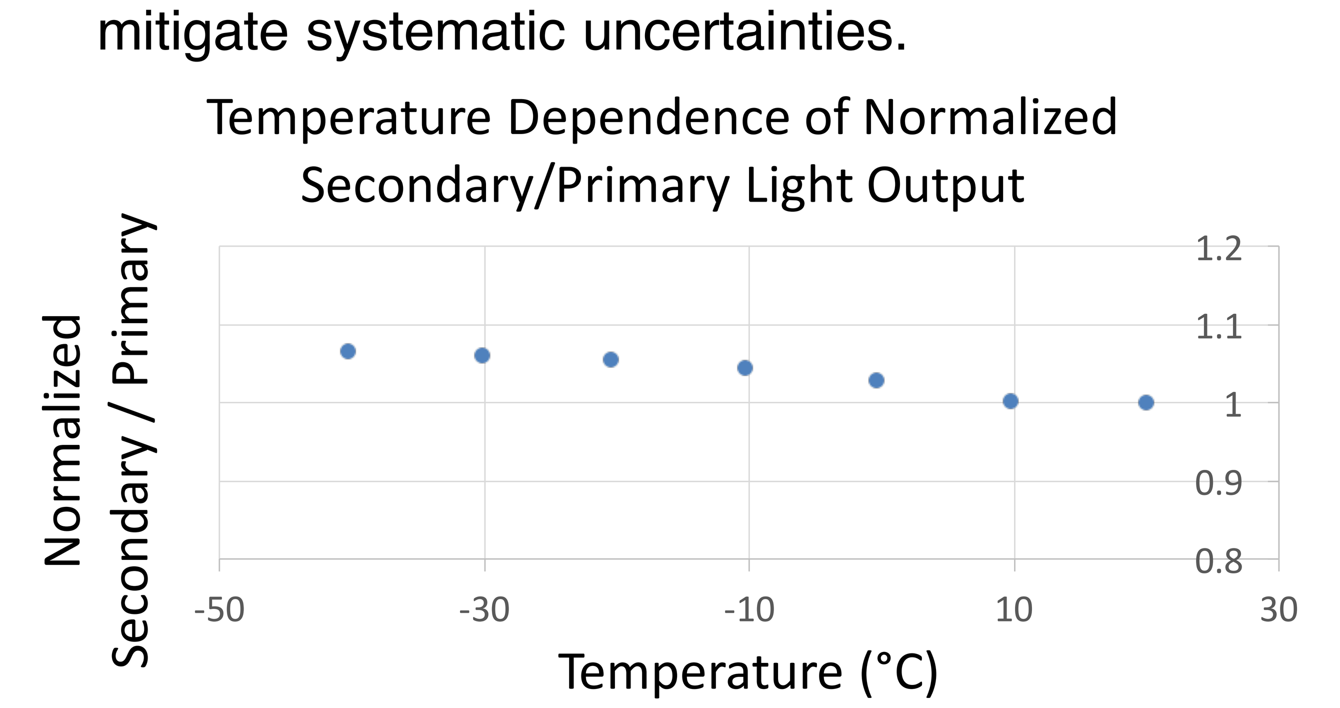
Results





Analysis

The charts above represent the temperature-dependent light output of the primary and secondary dopant. We expect these to be highly correlated, since the primary emission feeds the secondary emission. To observe how the behavior of these two emissions changes with temperature, the secondary was divided by the primary to see the ratio between the two emissions, and every data point was normalized to the output at 20°C to mitigate systematic uncertainties.



Conclusion

The light output of scintillator changes no more than 10% in the temperature range that CMS wishes to use (-30°C – 20° C). This is within acceptable tolerances. Additional studies of the temperature dependence of the radiation damage/performance of scintillator is underway.

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